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AN INVESTIGATION OF THE AIR FLOW AROUND A MARTIN PBM-3 FLYING BOAT BY MEANS OF TUFTS

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WASHINGTON

MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

AN INVESTIGATION OF THE AIR FLOW AROUND A MARTIN PBM-3 FLYING BOAT BY MEANS OF TUFTS

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INTRODUCTION

Observations by means of tufts have been made of the air flow around a Martin PBM-3 flying boat. These observations are part of an analysis being conducted by the NACA for the Bureau of Aeronautics to aid in the determination of possible methods of reducing the air drag of this airplane. The behavior of the tufts on the hull and tip floats at various airplane speeds has been recorded by still and moving pictures taken from an accompanying airplane; tufts on the wing, nacelles, radar fairing, and gun turrets were observed but not photographed.

METHOD AND TESTS

The investigation was made on the Martin PBM-3 (no. 6457) flying boat at the Naval Air Station, Norfolk, Va. (See fig. 1.) Satin ribbons 1/2 inch wide and $4\frac{1}{2}$ inches long were attached to the airplane with waterproof cement and were arranged in rows parallel to the base plane of the hull. The tufts were attached to both sides of the hull and on the bottom, the left tip float, the radar fairing, the engine nacelles, and the center section of the wing. The space between the tufts varied from 6 to 24 inches.

Still pictures were made of the airplane in the following conditions:

Indicated airspeed, knots	Lift coefficient, C_L (approx.)
94	1.02
116	.67
137	.48
166	.33

Motion pictures were also made at these conditions and a copy is included as part of this report.

RESULTS AND DISCUSSION

Photographs showing the alinement of the tufts on the hull and tip floats of the PBM-3 flying boat at the various airspeeds investigated are given in figures 2 to 9. Because some of the photographs are not clear, part of the following discussion is based on visual observations of the motion of the tufts.

At all airspeeds, the cross flow over the sharp forebody chine resulted in flow separation just above the chine line which caused the tufts in this region to stand away from the hull. The violence of the separation was greatest at the low airspeeds and the region influenced by the separation extended farther back along the sides of the hull. The tufts above the chine, for some distance behind the separated region, were deflected downward by the induced velocity resulting from the vortex motion over the sharp chine. The severe separation occurring at low airspeeds explains in part the high drags measured on flying-boat hulls at large angles of attack.

Above the chine along the sides of the hull, the flow was generally parallel to the direction of flight. The effect of the wing in deflecting the flow over the hull is plainly evident in figure 2. The flow over the tail extension, at an airspeed of 94 knots (fig. 2), was smooth and nearly parallel to the base line; no separation was apparent in this region. The flow around the stern post was affected to a large extent by the separation at the vertical step on the sides of the afterbody. Behind the main step, turbulence extended aft approximately 10 feet; from this point to the stern post, the flow along the bottom of the hull was smooth.

The flow over the starboard side of the hull was generally similar to that observed on the port side. (Cf. figs. 2 to 4.)

Increasing the airspeed from 94 to 116 knots caused only slight changes in the flow over the hull, as may be seen by comparing figures 2 and 5. The angle between the relative wind and the hull was decreased approximately 5°, and the tufts over most of the hull therefore lie more nearly parallel to the base line at the higher airspeed. Similar small changes in direction of flow were noted when the speed was increased from 116 to 137 knots. (See figs. 6 and 7.)

At 166 knots (the high-speed attitude) the flow along the sides of the hull was parallel to the base line (figs. 8 and 9). The inclination of the tufts along the forebody chine indicates an appreciable reduction in cross flow over this corner. Turbulence behind the main step, however, appeared to extend somewhat farther aft at this speed than for the lower speeds.

The effect of changes in flight speed and attitude upon the flow over the wing-tip floats is shown in figures 2, 5, 6, and 8. At 94 knots the tufts on the bottom of the float indicated a strong flow toward the chine; the tufts just above the chine were steady and appeared to stand away from the surface, again indicating a strong vortex in this region. The cross flow was still present at 166 knots, although it was less pronounced than at the lower speeds. The flow over the afterbody of the float and behind the strut fittings was turbulent at all speeds; however, the turbulence decreased at higher speeds.

The tufts behind the nose turret indicated slight turbulence ahead of the windshield at all airspeeds. Behind the deck turret the tufts oscillated continuously through an angle of approximately 30°, showing severe turbulence in this region.

Over the radar fairing the flow was generally smooth; tufts in the last two columns, however, were slightly unsteady. Turbulence was also apparent along the top of the hull aft of the radar installation.

The flow over the afterbody of the nacelle was always rough. This turbulence may have been caused in a large measure by the position of the cowl flaps which were partially open during the entire tests. At the lower speeds the flow over the upper surface of the afterbody of the nacelle was unsteady, but no separation in this region was indicated at any speed.

SUMMARY OF RESULTS

1. The air flow over the hull was generally parallel to the direction of flight.

2. As a result of the cross flow over the sharp forebody chine, flow separation occurred above the chine which caused the tufts in this region to stand away from the surface. The violence of the separation was greatest at low airspeeds.

3. A flow separation similar to that over the hull occurred above the chine on the tip float. Flow separation also occurred behind the step on the tip float at all flight speeds.

4. Flow separation occurred on the bottom of the hull for approximately 10 feet behind the main step. The length of the region of separation was greater at the high-speed condition. The flow was also disturbed behind the vertical steps on the sides of the afterbody.

5. The flow was turbulent over the engine nacelles, ahead of the windshield, around the juncture of the radar fairing, behind the top turret, and behind the tip-float strut junctures.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 16, 1943.

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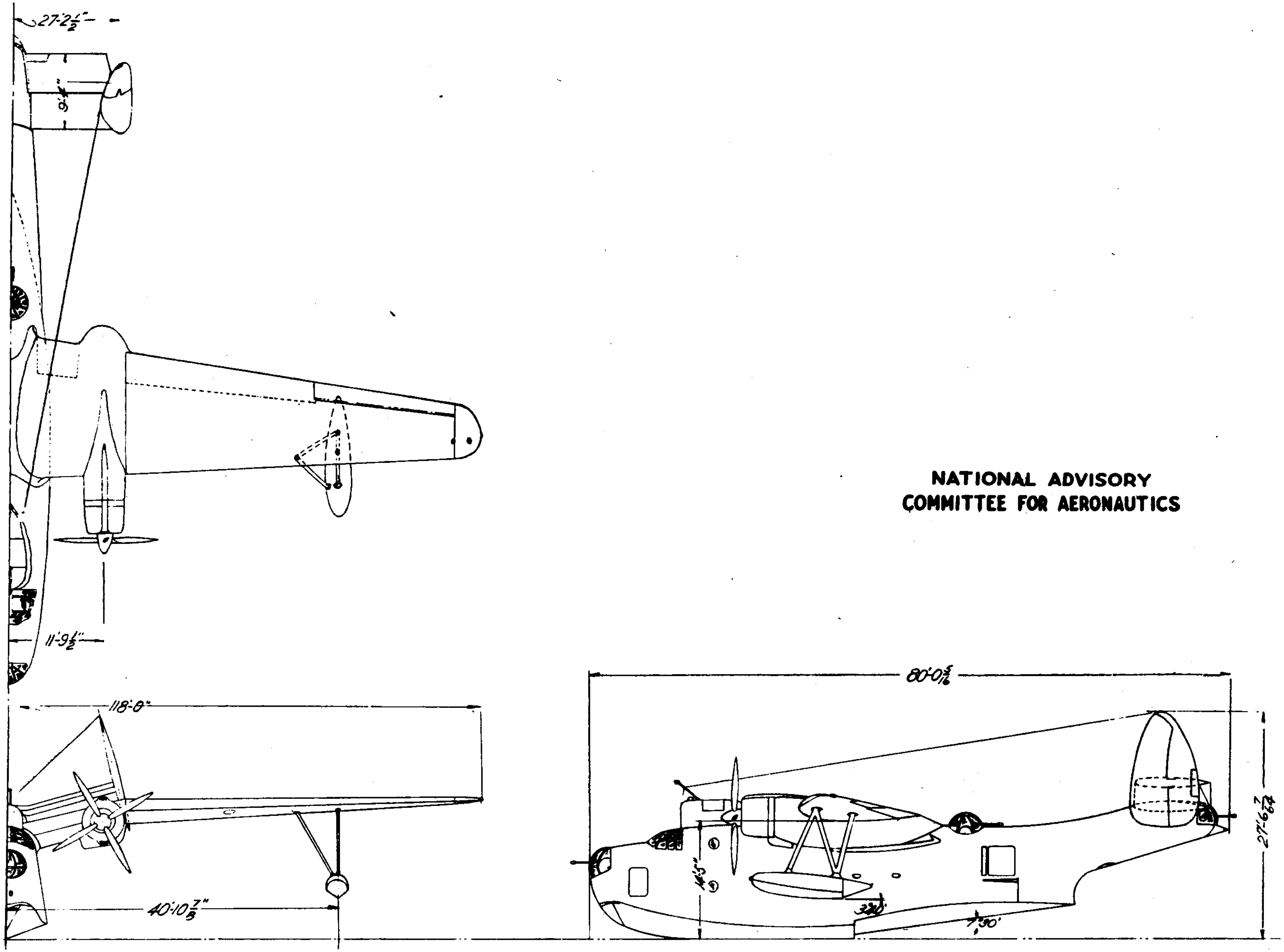

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Figure 1 General arrangement of PBM-3 airplane

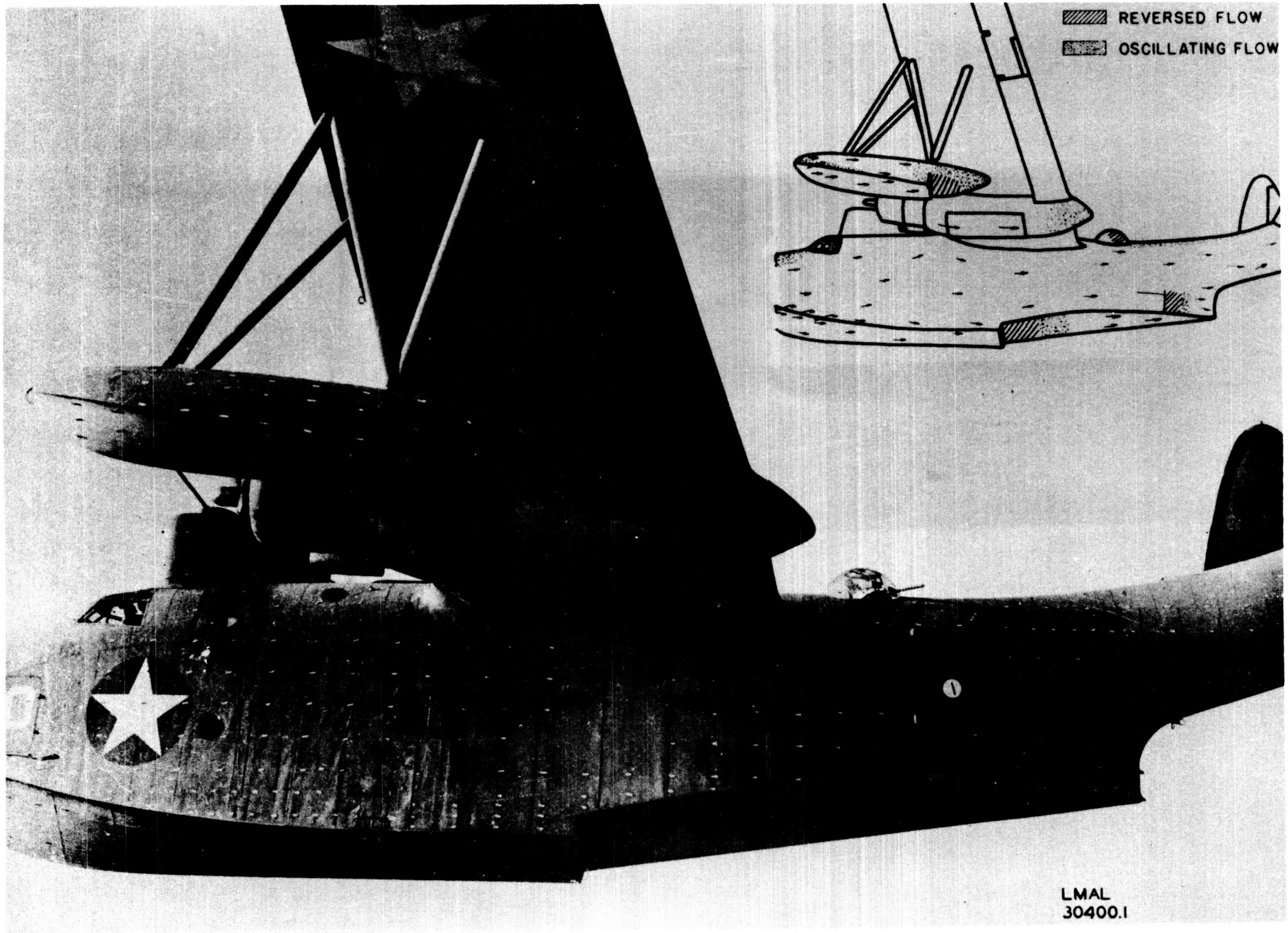

Figure 2.- Flow over a PBM-3 hull at 94 knots, indicated airspeed.

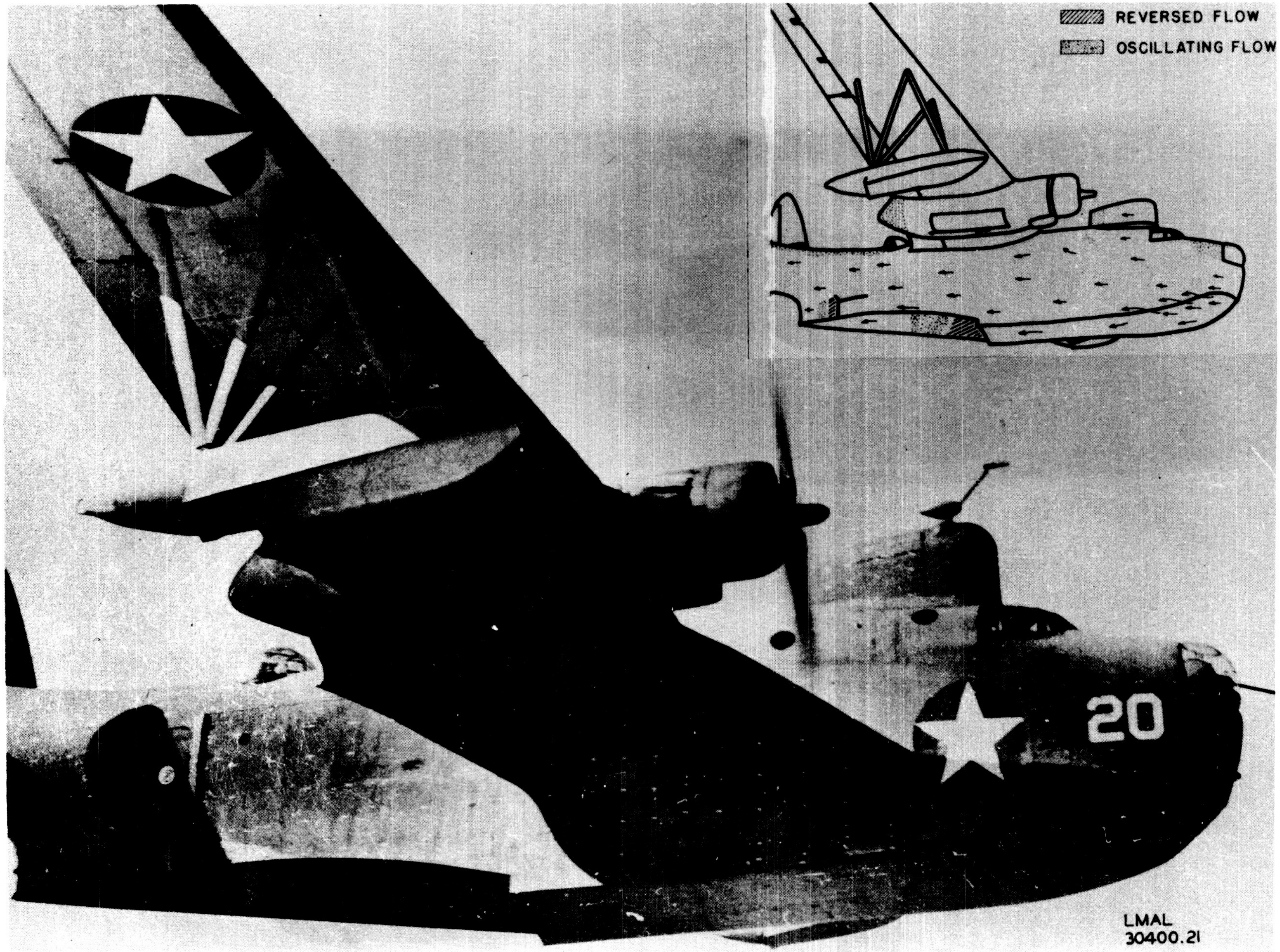

Figure 3.- Flow over a PBM-3 hull at 94 knots, indicated airspeed.

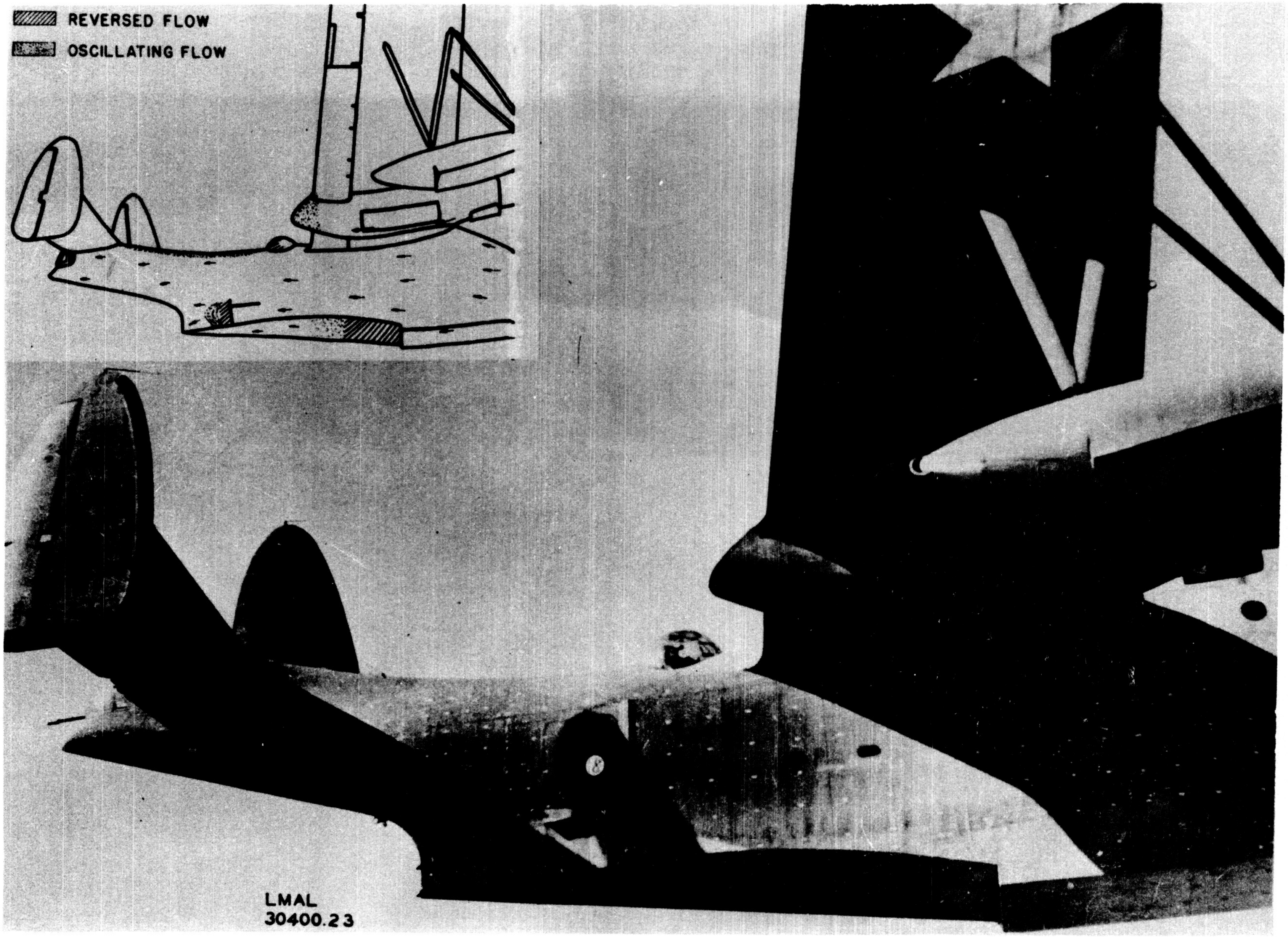

Figure 4.- Flow over a PBM-3 hull at 94 knots, indicated airspeed.

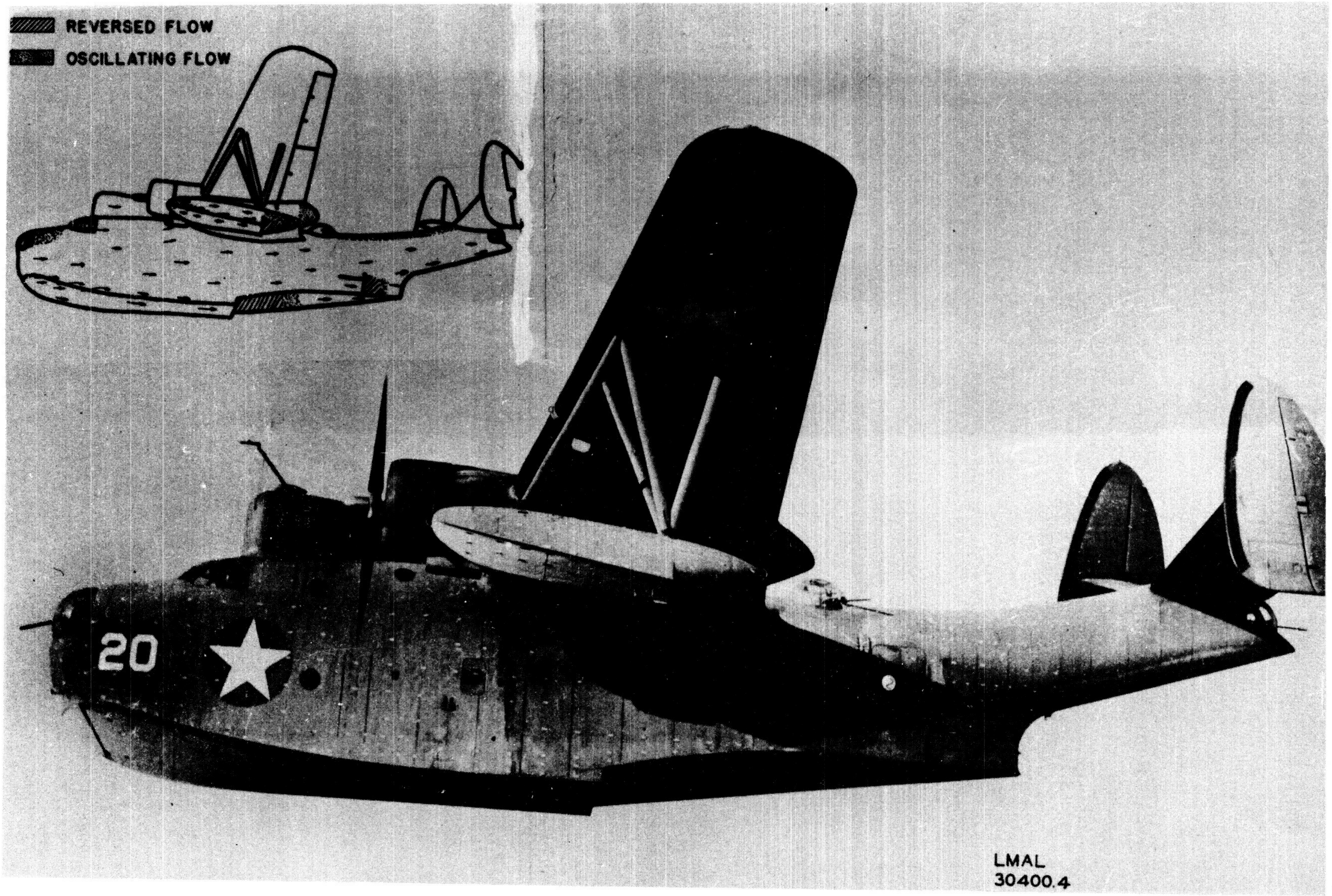

Figure 5.- Flow over a PBM-3 hull at 116 knots, indicated airspeed.

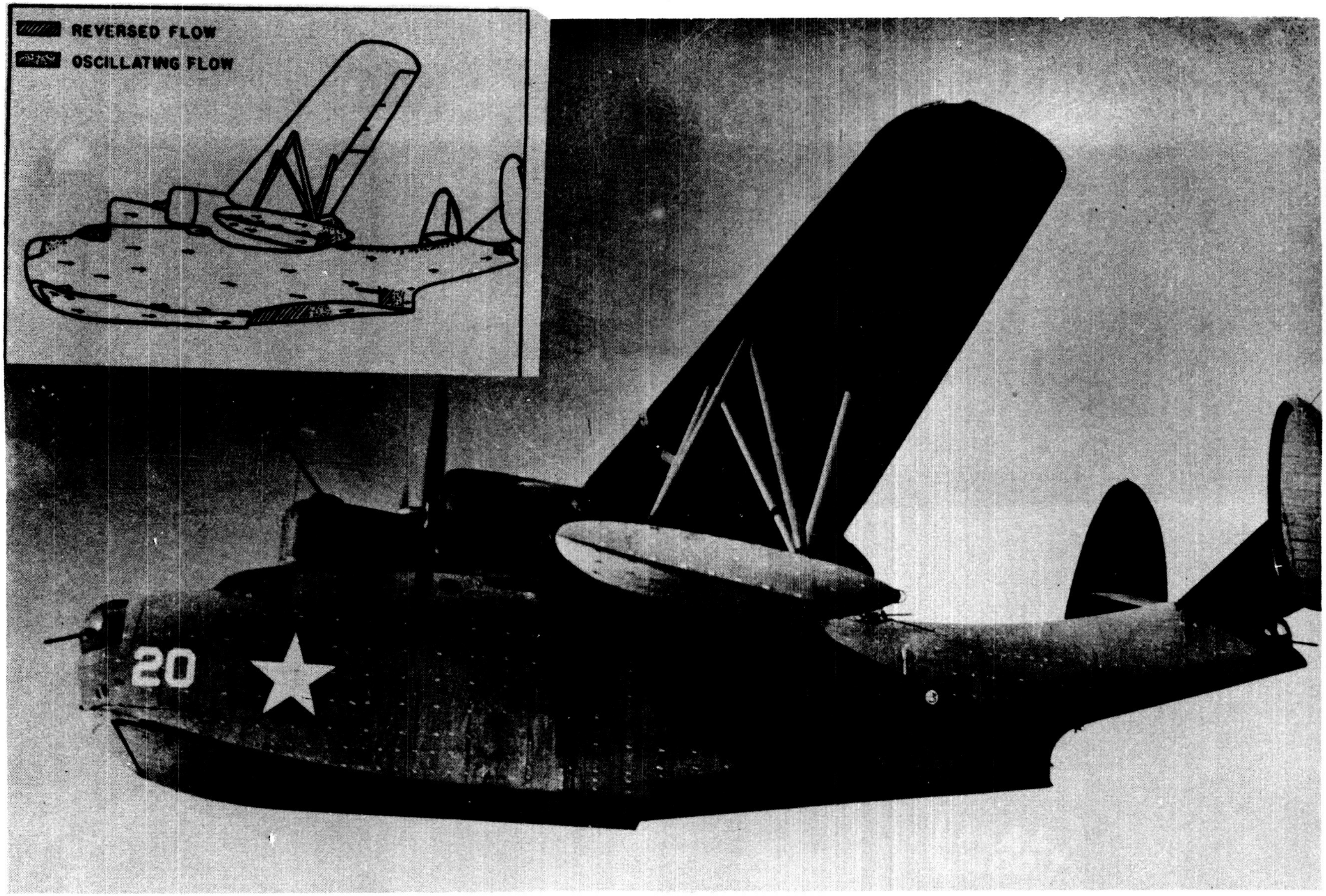

Figure 6.- Flow over a PBM-3 hull at 137 knots, indicated airspeed.

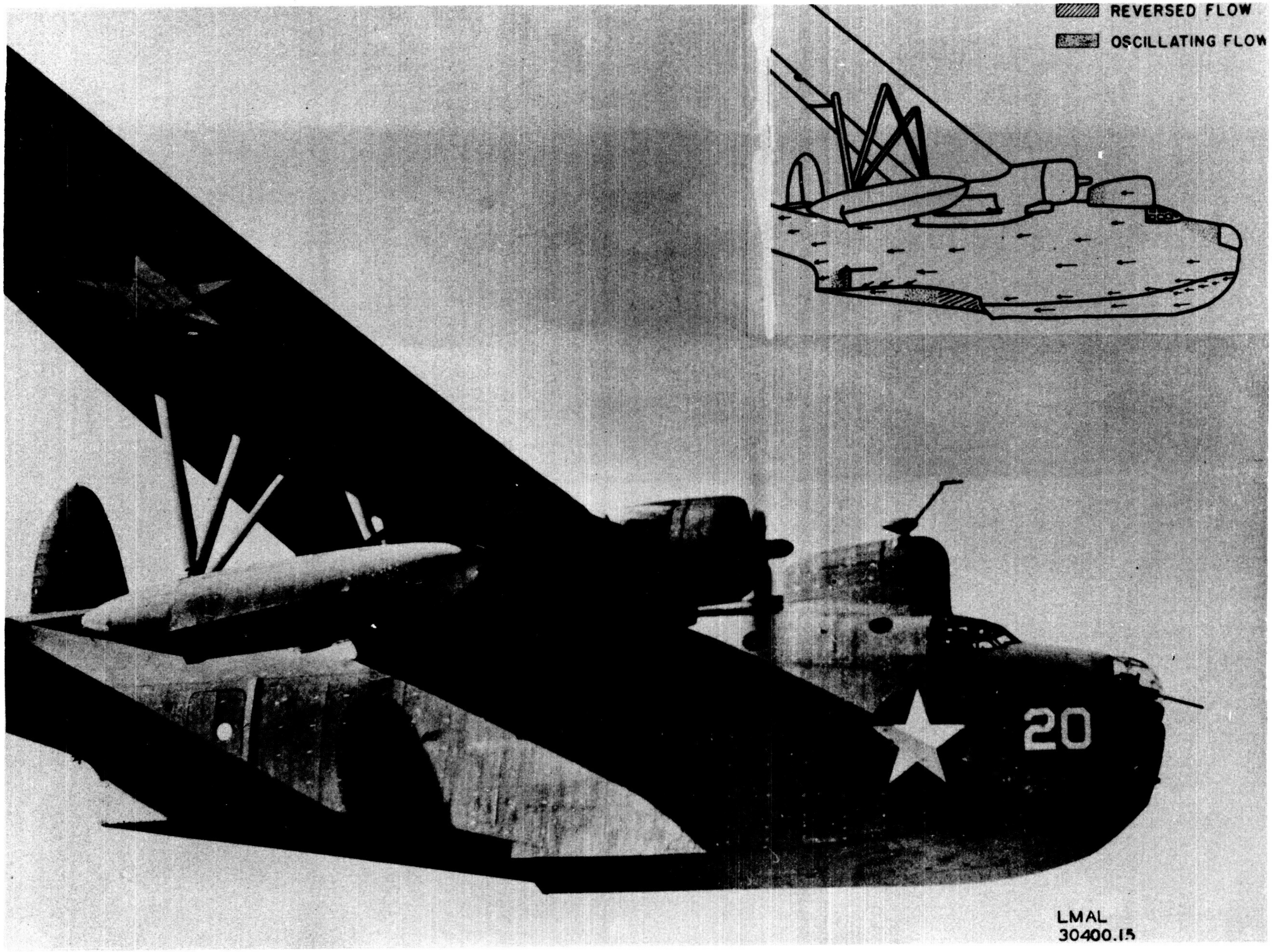

Figure 7.- Flow over a PBM-3 hull at 137 knots, indicated airspeed.

Figure 8.- Flow over a PBM-3 hull at 166 knots, indicated airspeed.

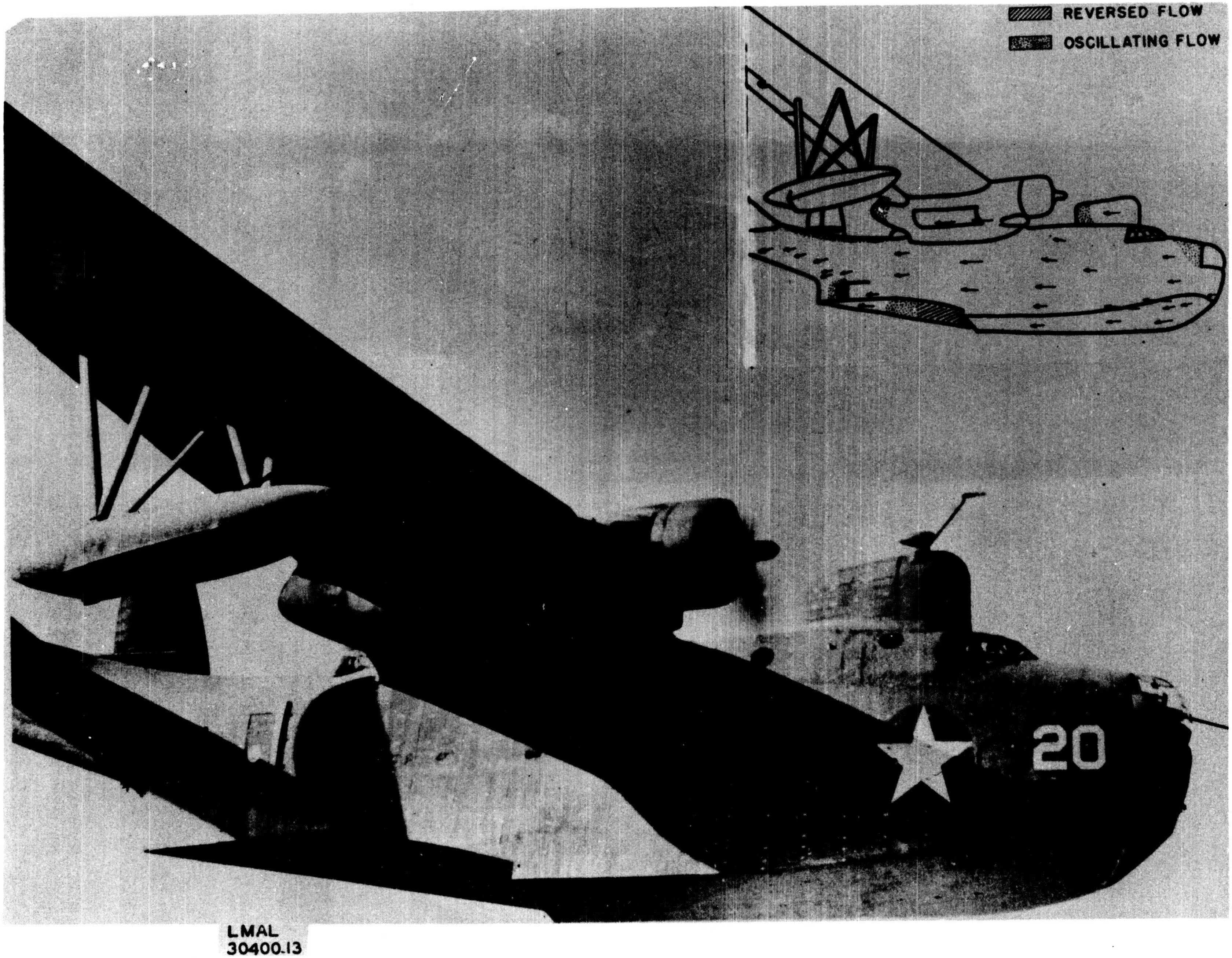

Figure 9.- Flow over a PBM-3 hull at 166 knots, indicated airspeed.